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The CPSC Road Test of Bicycle Braking Performance - Experimental Evaluation

Donald E. Marlowe

Engineering Mechanics Section
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National Bureau of Standards
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U.S. DEPARTMENT OF COMMERCE, Rogers C.B. Morton, *Secretary*
James A. Baker, III, *Under Secretary*
Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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THE CPSC ROAD TEST OF BICYCLE BRAKING PERFORMANCE - EXPERIMENTAL EVALUATION

Donald E. Marlowe

ABSTRACT

The brake performance criteria to be published as part of a mandatory regulation on bicycle safety requirements has been evaluated. Fifteen bicycles were tested in accordance with the regulation. A mathematical adjustment of the actual test speed of the bicycle to 24 km/hr (15 mph) is necessary before the weight allowance can be made to the stopping distance in the evaluation of these tests. A danger of injury to the test rider exists during the tests and future efforts should be made toward replacement of these tests with a simpler laboratory procedure.

Key Words: Bicycles; braking; consumer safety; handbrake; safety; testing.

1. SCOPE

Accident reports received by the Consumer Product Safety Commission list many injuries to children as a result of accidents involving bicycles. Many of these injuries result from the inability of the bicycle to stop quickly in an emergency situation. As a result, the Commission has included a series of handbrake performance criteria in the mandatory regulation on bicycle safety requirements which they have prepared.

1.1 Test Purpose

This report describes tests which were performed at the National Bureau of Standards as a partial evaluation of the braking tests called for in the Federal Bicycle Safety Regulation, Requirements for Bicycles, July 16, 1974 [1]. These tests included the Loading Test (1512.18(d)(2)(i)) the Rocking Test (1512.18(d)(2)(iii)) and the Performance Test (1512.18 (d)(2)(v)).

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*The numbers in parentheses refer to paragraphs of the proposed regulation.

1.2 Test Equipment

The test equipment assembled for these tests included a force gage, handbrake loading assembly, an electronic timer for measurement of bicycle velocity, a ground position marker gun assembly and a level paved surface upon which to perform the tests.

1.3 Test Flow

The flow of procedures followed in these tests is shown in Figure 1.

2. APPARATUS

2.1 Handbrake Lever Loading Fixture

A loading fixture (Figure 2) which incorporates a 445 N (100 lbf) spring force gage and a gripping linkage for attachment to the brake lever was fabricated for these tests. This apparatus was based on a design which had been developed at the University of Iowa. In use, the apparatus is mounted on the handlebar (Figure 3) and grips the brake lever. The rider applies force to the apparatus lever. This lever pushes up on the force gage which is connected through the linkage shown to the brake lever. An engineering drawing of this apparatus is provided in the Appendix. At the instant the rider begins to apply force to the lever, a switch on the force gage is closed and the ground marker system is actuated. A second switch could be actuated at a predetermined force level.

2.2 Ground Marker System

The marker system is used to indicate on the ground the point at which the brakes were first applied. For these tests, a marker gun designed for use as an automobile driver education aid was modified for mounting on a bicycle. The system (Figure 4) included the double barreled gun, a twelve volt battery, the switches mounted on the loading assembly, the marker cartridges which are supplied with the gun, and the wiring necessary to connect the switch, gun, and battery in series. The marker cartridges contained a yellow, quick drying paint. During the tests reported here, for the bicycles equipped with handbrakes, a first cartridge was fired at the instant brakes were applied and a second at the instant the applied force equaled 178 N (40 lbf). The distance between the two marks so produced was used to estimate the rider's actuation time for the system. In addition, several tests were conducted with a second, nominally identical gun system mounted on the bicycle. This system was wired to the opposite side loading assembly and could be used to estimate the left-hand-right-hand coordination of the brake levers.

For the tests on bicycles equipped with a coaster brake, the marker system was actuated by the backward motion of the drive chain as the brake was applied (Figure 7).

The batteries used to actuate the solenoid in this system posed a special problem. In the use for which the solenoid fired gun was designed, the power from an automobile battery is used, and is continuously recharged. In this application, the first tests were made using two, 6 volt lantern batteries connected in series. These quickly discharged to a point where they would no longer actuate the solenoid and had to be replaced. This often occurred before testing could be completed on one bicycle. To eliminate this problem, a rechargeable 12 volt battery used to start a walk behind lawn mower was chosen. The battery had enough capacity to allow the testing of up to 3 bicycles before it needed recharging.

2.3 Timer

An electronic timer, capable of measuring the elapsed time between two similar events to within one microsecond, was used to record the time interval between passage of the bicycle wheels over a tape switch on the ground. Knowing the elapsed time and the wheel base of the bicycle, the velocity of the bicycle could be calculated. The equipment used is shown in Figure 5. It shows the timer, a 1.5 m (5 ft) long ground tape switch, and a battery to power the switch circuit.

3. TEST CONDITIONS

3.1 Test Surface

The test surface required for these tests is a dry, clean, level, paved surface of a length adequate to accommodate the bicycle during the performance test. For these tests, an outdoor asphalt parking lot approximately 90 m (300 ft) long was used. The measured slope of this surface was 0.3 percent. To compensate for the effects which this slope and prevailing winds might have on the average stopping distance, alternate braking tests were made in opposite directions across the timing strip. Before any tests were conducted, any moisture which might have accumulated on the surface during the previous night was allowed to dry. The coefficient of static friction was measured between this surface and the tire of one bicycle included in this program. This will be discussed in section 6.3.

3.2 Rider

As has been realized from the beginning of these tests, the largest variable is probably the test rider. While the tangible effects of his weight on stopping distance can be allowed for, other rider related effects such as reaction time, agility, anticipation and confidence

have not been well quantified. Several measurements were made during these tests in an effort to define reaction time and agility (the ability to coordinate left-hand-right-hand brake actuation). The problem of rider confidence, or lack of it, has so far defied numerical measurement. Five riders have tested bicycles for this program. Several bicycles were tested by more than one rider. A discussion of these tests will be given later. It should be noted here, however, that every rider crashed at least one bicycle. For this reason, all test riders should be equipped with suitable safety equipment, including a helmet, to minimize the injuries possible during an accident.

4. PROCEDURE

The following is a detailed description of the procedure followed during testing in accordance with paragraph 1512.18 (d) of the proposed regulation:

1) Assemble the bicycle according to the instructions provided by the manufacturer.

2) Inflate the tires to the pressure molded into the tire sidewall. Record the tire pressure.

3) The test rider should ride the bicycle to familiarize himself with its behavior in the various gear ratios and under rapid braking conditions.

4) Determine the bicycle payload by weighing the on-bicycle test equipment and rider. Record the weights.

5) Measure and record the wheel base of the bicycle. This measurement is made from the center of the front axle to the center of the rear axle.

4.1 Set-up for Primary Handbrake Lever

1) Adjust the position of the brake lever on the handlebar so that the lever will be pulled vertically by the action of the force gage during testing. This may involve changing the location of the levers on the handlebars such that they are generally below the lowest part of the handlebar (Figure 6).

2) Tighten the clamp to the lever, 25 mm (1 in) from the lever end (Figure 6).

3) Adjust the stops on the force gage to apply a maximum of 178 N (40 lbf) to the brake lever. If the clamp bottoms against the handlebar,

at a load less than 178 N (40 lbf), adjust the position of the clamp on the lever to insure that the lever bottoms against the handlebar.

4) Adjust the length of the linkage from the force gage to the clamp so that the brake system is fully relaxed and no braking forces are being applied to the brake levers.

5) Tighten the clamp of the force gage to the handlebar.

6) Make a final adjustment of the brakes according to the operating instructions. No further brake adjustments are allowed by the regulation after this adjustment (1512.18(d)(2)).

7) Install the ground marker gun on the front fork of the bicycle (Figure 4). Strap the battery to the bicycle.

8) Connect the battery to the marker gun switches and guns.

9) Photograph the bicycle with the test hardware mounted on the bicycle.

10) Wipe the braking surface of the tire rims with alcohol to remove any residue from earlier bicycle use.

4.2 Set Up for Extension Hand Brake Lever

1) Adjust the position of the extension lever on the handlebar so that the lever will be pulled vertically by the action of the fingers during testing.

2) Install the firing switch on the extension lever and the ground marker gun on the fork.

3) Make a final brake adjustment according to the manufacturer's operating instructions.

4) Install the battery and necessary wiring.

5) Photograph the bicycle with the test hardware mounted on the bicycle.

6) Wipe the braking surface of the tire rims with alcohol to remove any residue from earlier bicycle use.

4.3 Set Up for Coaster Brake Systems

1) Install the ground marker gun on the bicycle fork.

2) Install the firing switch on the seat tube so that the chain reversal caused by the braking action causes the switch to catch in the chain, and actuate the switch (Figure 7).

3) Install the battery and necessary wiring.

4) Photograph the bicycle.

4.4 Testing

The following tests shall be performed on all bicycles. The test sequence will be in accordance with the flow diagram (Figure 1). For a detailed procedure for bicycle brake testing see a Procedure for Testing Bicycle Braking Performance [2]. A sample data sheet for recording the braking test information is shown in Figure 8.

4.4.1 Handbrake Loading Test

On all bicycles equipped with handbrake levers and/or extension levers, perform the Handbrake Loading (1512.18(d)(2)(i)) by applying 445 N (100 lbf) to the brake levers or by bottoming the hand levers against the handlebars, whichever comes first. This test may require removal of the stops on the force gage (Figure 6) to allow full travel of the gage. This load shall be applied and removed 10 times.

4.4.2 Rocking Test

On all bicycles equipped with handbrake levers and/or extension levers, perform the Rocking Test (1512.18(d)(2)(iii)) by placing the test rider on the bicycle and, with the brakes loaded as in the Loading Test, drag the bicycle 6 times forward and 6 times rearward for a distance of 75 mm (3 inches) each way.

4.4.3 Performance Test

1) Set the stops on the force gages to 178 N (40 lbf) applied to the brake lever and adjust the switches on the marker guns so that the guns fire upon first actuation of the brake levers and at 178 N (40 lbf) or the maximum load.

2) Set up the elapsed timer and triggering tape switch on the test pavement.

3) Load the ground marker guns.

4) Conduct stopping runs according to the Handbrake Performance Test (1512.18(d)(2)(v)) while traveling in opposite directions across the timing switch.

5) Measure the stopping distance from the rearmost ground mark to the corresponding gun on the bicycle. Make the measurement along the original line of travel of the bicycle. Disregard the changes in path line which occur during the test.

6) Compute the stopping distance, making the corrections for bicycle velocity and payload. A sample calculation is shown in Figure 9.

5. TEST RESULTS

The specimen parameters for the 15 bicycles tested are given in Table 1. The stopping distances for the bicycles measured during this evaluation of the test method are given in Table 2. It is estimated that the errors in the measurement of elapsed time did not exceed 0.0001 seconds, and that the errors in stopping distance measurement did not exceed 0.03 m (0.1 ft).

6. DISCUSSION

It should be noted early in this discussion that the apparatus assembled for these tests is not unique. Several alternate ways of measuring the lever forces or bicycle velocity could have been devised.

A further note about rider safety is necessary here. These tests are performed at relatively high speeds on a paved surface. There exists a danger of an accident, resulting in possible injury to the rider. Accidents occurred during testing of four of the fifteen bicycles used in this program. It is significant that every test rider had at least one accident. After these accidents, several of the riders declined to test another bicycle.

6.1 Loading and Rocking Tests

In general, the flow (Figure 1) and procedures for these two tests and the performance test are not specified in the proposed regulation and evolved during the test evaluation and hardware development period.

All bicycles equipped with handbrakes were tested for compliance with the loading test and rocking test. All bicycles passed these tests with the exception of bicycle 9. One of the brake pads on the front caliper of this bicycle was dislodged from its holder during the rocking test. The pad was replaced in the holder, and the rocking test was repeated with no further failures.

6.2 Braking Tests

Tests were performed on 15 bicycles equipped with many of the handbrake-footbrake combinations currently available. A recurrent problem throughout these tests was the difference in equipment and arrangement among the several bicycles. To some extent, every bicycle tested became a separate project.

As was indicated above in section 4.4.3, the bicycle stopping distance of interest has been interpreted to be the straight line distance from the first ground mark to a point opposite the marker gun along the original line of travel of the bicycle. This distance was chosen instead of the distance along the path over which the bicycle traveled during the stop, because it is the shorter of the two distances and represents the minimum distance needed to stop during an emergency situation. In addition to the measured stopping distance, table 2 shows the stopping distance corrected by adjusting the bicycle speed to 24 km/h (22 fps) and the bicycle payload to 68.1 kg (150 lb).

It was necessary to make the velocity correction because the weight allowance provided for in the regulation assumes that the bicycle is moving at 24 km/h (15 mph).

In addition, the percent variation in the corrected stopping distances is shown. Most of the bicycles tested were capable of meeting the acceptance criteria of the regulation after the above two adjustments to the stopping distance had been made. The percent variation in stopping distance after these adjustments ranged from 8 percent to 144 percent. Three bicycles failed to stop from the required speed within 4.5 m (15 ft).

An analytical study of these and other variables which affect these tests is presently being carried out [3]. This study contributed to these procedures in the areas of data reduction and in the averaging of the effects of weather and pavement. The data from these tests will be used in the evaluation of the analysis.

6.3 Coefficient of Friction and Effect of Pavement Surface

A coefficient of friction measurement of two different test surfaces was made using one bicycle. The stopping distance of this bicycle on these surfaces under nominally identical conditions was compared.

The coefficient of friction was measured by locking the rear wheel of the bicycle. With 45.4 kg (100 lb) of weights placed on the seat, the force exerted on the ground by the rear wheel was measured. A force gage was attached to the rear tire near the ground and a gradually increasing horizontal force was applied until the tire slipped on the pavement. The two surfaces tested in this way were the paved parking lot which was normally used for testing, and an unpainted, smooth concrete laboratory floor. The results of these tests are shown in Table 3.

6.4 Rider Reaction Times

As was discussed above, several bicycles were instrumented to measure the brake force application time and the left-right coordination of the brake handles. The results of these tests are given in Table 4.

These times are within the range of times reported for similar testing at other laboratories.

6.5 Effect of Rider Weight

As can be seen from Table 2, two bicycles were tested by several riders of different weights. The results from these tests are inconclusive. While the raw stopping distances tended to be longer for the heavier rider, as expected, the corrected distances did not show such a trend. This can be seen best in the data reported for bicycle 8 tested with extension levers.

7. CONCLUSIONS

The tests on brake systems proposed for the mandatory Requirements for Bicycles have been performed on several representative samples. A mathematical adjustment of the actual test speed of the bicycle to 24 km/h (15 mph) should be permitted by the regulation before the weight allowance correction is made to the stopping distance for the proper evaluation of the braking performance by these tests. Twenty percent of the specimens failed to stop within the required distance. All of these were equipped with caliper brakes on both wheels. An analytical study which discusses the effect of many variables on stopping distance is being developed. A danger of injury to the test rider exists during the performance tests and future efforts might be made toward replacement of this, and possibly the other brake tests, with a simpler, laboratory procedure.

8. REFERENCES

The documents which are applicable to these tests include:

1. Requirements for Bicycles, Part 1512, Federal Register, Vol. 39, No. 137, July 16, 1974, and its admendments.

2. Marlowe, D. E., A Procedure for Determining Bicycle Braking Performance, NBSIR 75-953, in preparation.

3. Mordfin, L., The CPSC Road Test of Bicycle Braking Performance - Kinetic and Error Analysis, NBSIR 75-786, in preparation.

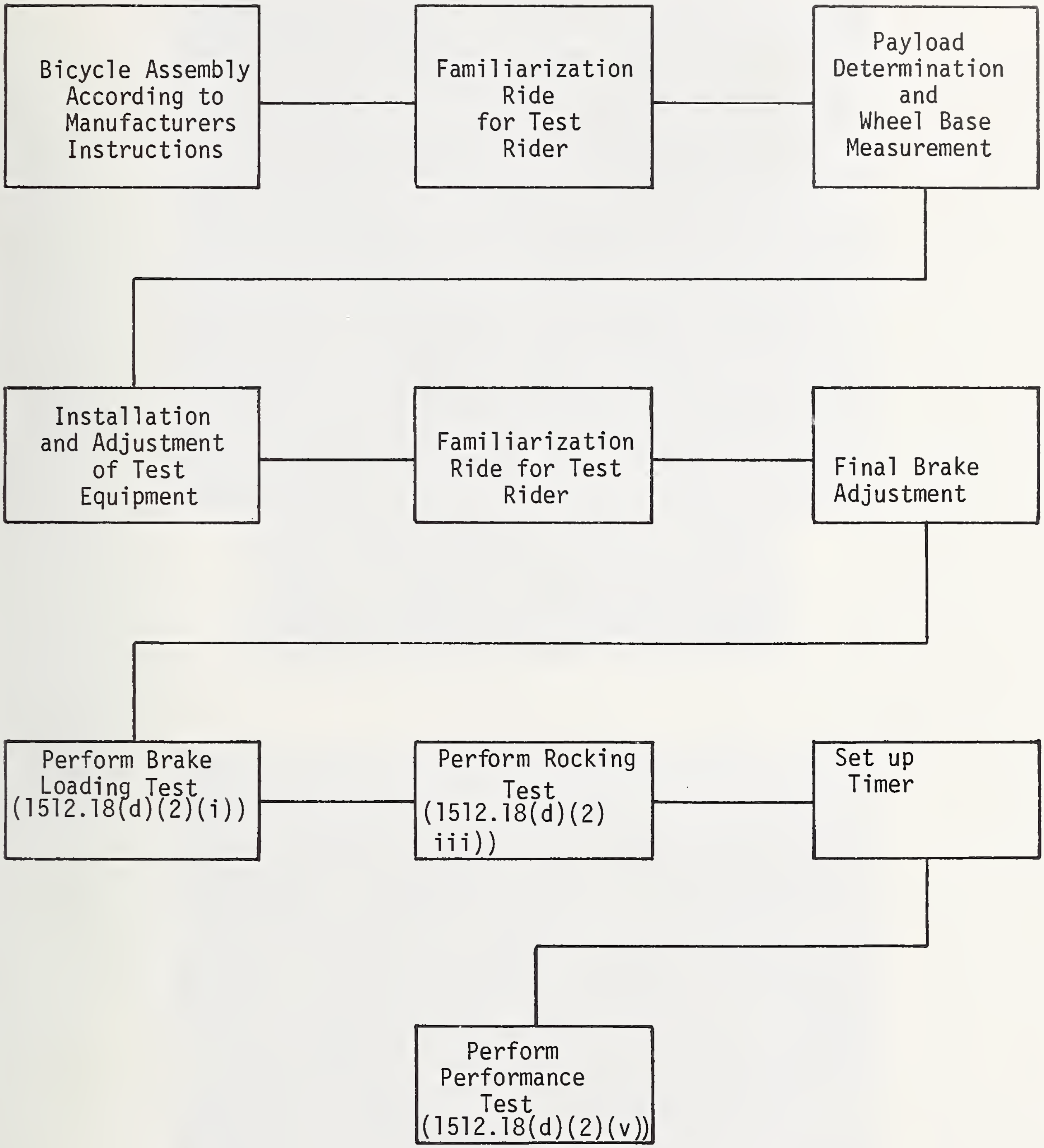

Figure 1 - Flow Diagram for Handbrake Tests

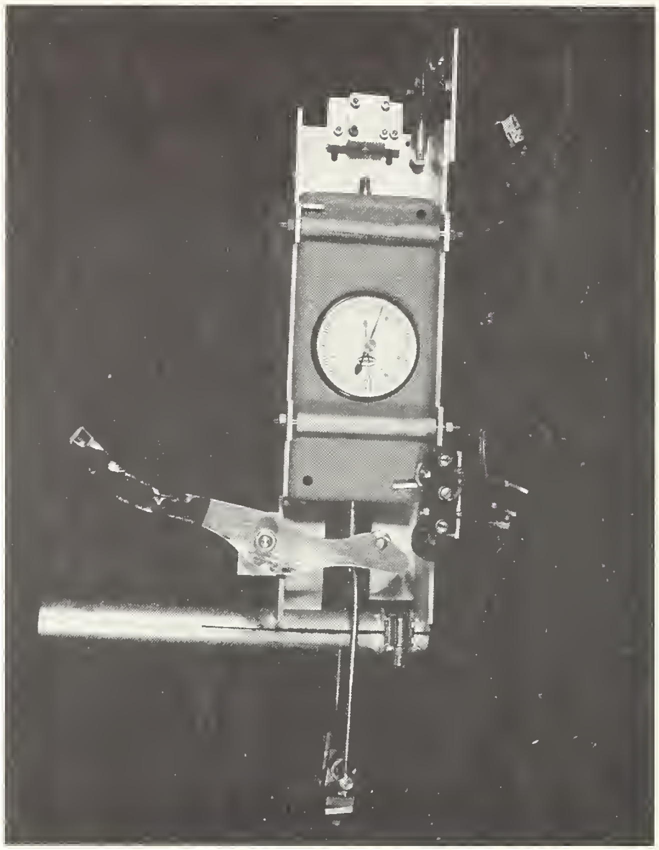

Figure 2 - Handbrake Loading Fixture

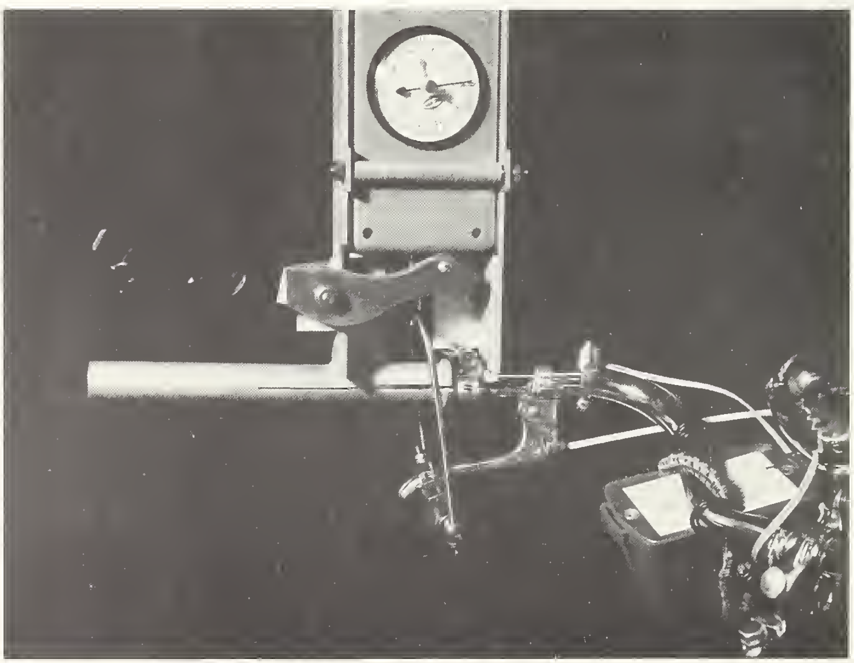

Figure 3 - Loading Apparatus on a Bicycle

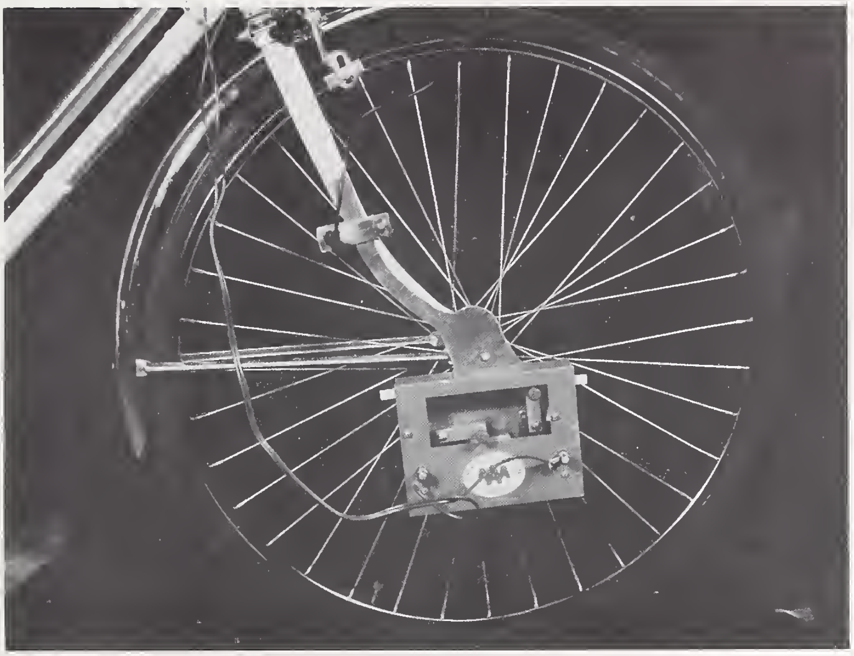

Figure 4 - Ground Marker System

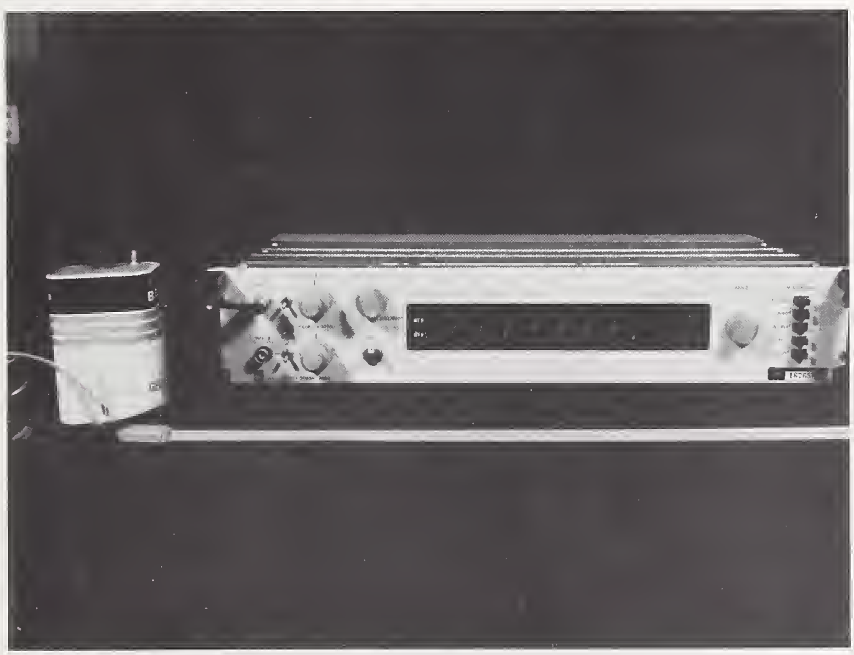

Figure 5 - Velocity-Timer Apparatus

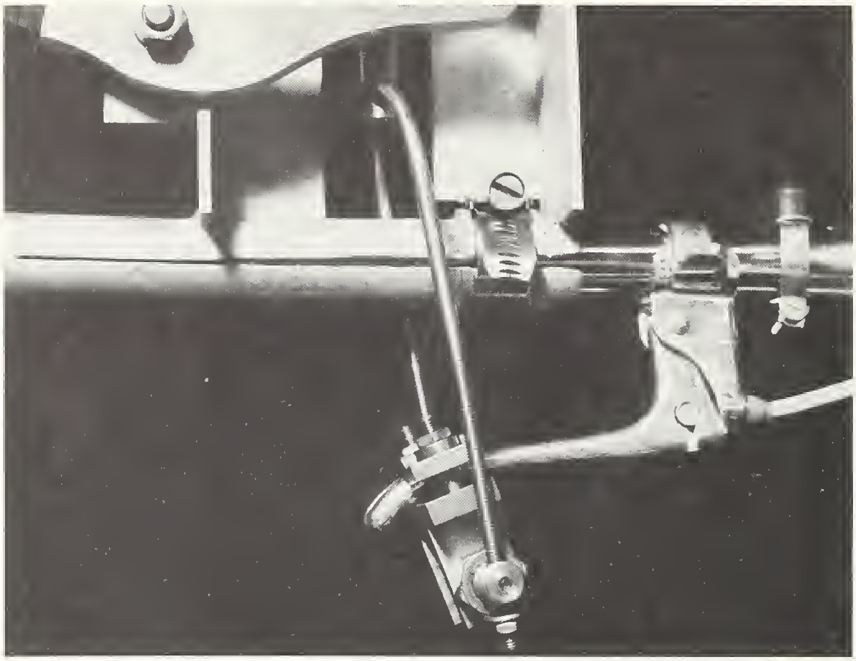

Figure 6 - Loading Apparatus Clamp on Brake Lever

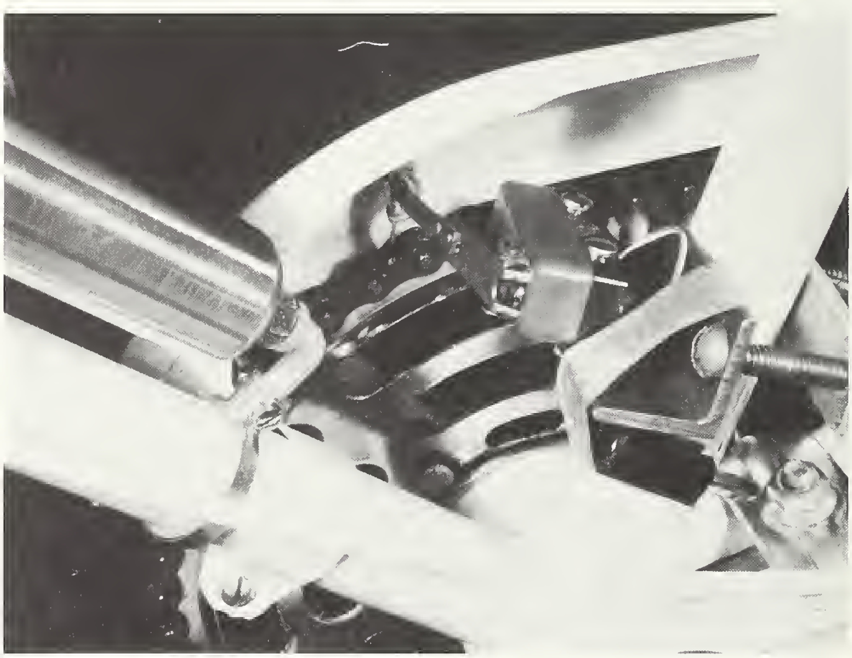

Figure 7 - Firing Switch for Coaster Brakes

BRAKING TEST DATA SHEET
PREPARE ONE FOR EACH BICYCLE

a) Bicycle Manufacturer ________________

Serial No. ________________

Model No. ________________

b) Test Date ____________

c) Rider ______________

d) Bicycle Information

Wheel Size ________________ in

Max Gear Ratio ________________

Brake Type ________________

Brake Mfg. ________________

Frame Size ________________ in

e) Test Information

Wheel Base ____________ in

Equip. Weight ________ lbf

Rider Weight ________ lbf

f) Loading Test

Load on Force Gage ____________ lbf

Lever Hit Bar ________________

Pass-Fail

g) Rocking Test

Pass-Fail

h) Performance Test

Run No.	Elapsed Time for Speed Measurement	Direction of Run	Stopping Distance from Rear most Marker	Distance Between Markers: L-R Coordination	Distance Between Markers: Application of 40 lbf	Skidding
	sec		ft	ft	ft	

Figure 8 - Braking Test Data Sheet

Bicycle Manufacturer
Serial No.

Bicycle Run No.	Speed Elapsed Time A	Wheel Base B	Speed C	Measured Stopping Distance D	Speed Corrected Distance E	Bicycle Payload F	Load Corrected Distance G	Run Direction H	Average best Distance I
	sec	ft	ft/sec	ft	ft	lb	ft		ft
1	.1547	3.462	22.38	16.66	16.10	214	9.70	S*	
2	.1519		22.79	17.50	16.30		9.90	N*	
3	.1404		24.66	21.75	17.30		10.90	S	
4	.1509		22.95	17.83	16.39		9.99	N	
5	.1574		23.49	19.92	17.47		11.07	N	
Avg.									9.80

*Indicates runs used to compute average best.

$$\text{Speed} = \frac{\text{Wheel Base}}{\text{Elapsed Time}}$$

$$\text{Speed Corrected Stopping Distance} = \left(\frac{\text{Nominal Speed}}{\text{Actual Speed}}\right)^2 \text{Stopping Distance}$$

Load Corrected Distance = Speed Corrected Distance ±1 ft/10 lb of Payload over 150 lb.

Average best Distance = Arithmetic Average of Shortest Stopping Distances computed for each Direction in which Stopping Runs were made.

Figure 9 - Bicycle Performance Test Sample Calculation

Table 1 - Test Specimen Parameters

Bicycle No.	Brake Type	Number of Speeds	Maximum Gear Ratio	Wheel Size		Bicycle Mass		Wheel Base		Frame Size[d]	
				mm	in	kg	lb	mm	in	mm	in
1	Coaster and Single Caliper	1	40/16	508	20	14.1	31.1	887.7	34.95	349.2	13.75[a]
2	Double Caliper[e]	10	52/14	686	27	11.8	26.0	1027.7	40.46	527.0	20.25
3	Double Caliper	3	48/20	660	26	18.2	40.1	1051.6	41.40	527.0	20.75
4	Double Caliper	10	52/14	686	27	13.9	30.5	1088.6	42.86	635.0	25.00
5	Double Caliper with Extension Levers	10	50/14	686	27	13.4	29.5	1025.6	40.38	485.6	19.12[a]
6	Double Caliper with Extension Levers	10	52/14	660	26	15.0	33.1	1041.4	41.00	552.5	21.75
7	Double Caliper	10	50/14	686	27	18.4	40.4	1071.1	42.17	508	20.00
8	Double Caliper	10	52/14	686	27	16.8	37.0	1055.4	41.55	552.5	21.75
9	Double Caliper	10	52/14	660	26	15.2	33.5	1044.4	41.12	552.5	21.75
10	Double Caliper	5	50/14	686	27	16.6	36.6	1058.2	41.66	590.5	23.25
11	Coaster	1	36/16	508	20	13.9	30.5	894.6	35.22	352.3	13.87

(continued)

Table 1 - (Continued)

Bicycle No.	Brake Type	Number of Speeds	Maximum Gear Ratio	Wheel Size		Bicycle Mass		Wheel Base		Frame Size[d]	
				mm	in	kg	lb	mm	in	mm	in
12	Double Caliper with Extension Levers	10	52/14	610	24	15.6	34.4	1019.0	40.12	498.3	19.62
13[c]	Coaster	1	34/20	406	16	13.0	28.6	768.3	30.25	N.A.	N.A.
14[c]	Coaster	1	26/18	406	16	11.9	26.1	749.5	29.51	266.7	10.5[b]
15	Double Caliper	3	36/14	508	20	9.8	21.5	810.3	31.90	396.7	15.62

(a) Girl's Bicycle

(b) Convertable

(c) Sidewalk Bicycle

(d) Frame size measured from the center of the crank to top of the seat tube

(e) Caliper brakes on front and rear wheels

Table 2 - Braking Test Results

Bicycle No.	Bicycle Speed Elapsed Time A	Wheel Base B	Speed B/12A= C	Stopping Distance D	Speed corrected Distance $E=(22/C)^2D$	Bicycle Payload (a) F	Load corrected Distance G	Direction H	Avg best I (e)	% Var $(\frac{Max}{Min}-1)100$ J
	sec	in	ft/sec	ft	ft	lb	ft	N or S	ft	
PRIMARY BRAKING SYSTEM										
1	.1319	34.95	22.08	14.33	14.22	164	-	N*	14.91	39
	.1362		21.38	14.75	15.61		-	S*		
	.1323		22.01	19.25	19.22		-	N		
	.1325		21.98	16.33	16.36		-	S		
2	.1372	40.46	24.57	15.08	12.08	212.3	5.85	S*	9.28	233
	.1606		20.99	17.25	18.94		12.71	N*		53(d)
	.1571		21.46	23.08	24.25		18.02	S		
	.1477		22.82	27.66	25.69		19.46	N		
3	.1539	41.40	22.41	15.00	14.44	194.3	10.01	N*	10.00	30
	.1469		23.48	16.42	14.41		9.98	S*		
	.1448		23.82	18.75	15.99		11.56	N		
	.1585		21.77	17.08	17.44		13.01	S		
4	.1392	42.86	25.66	22.42	16.48	212.3	10.25	S*	10.58	8
	.1577		22.65	18.17	17.14		10.91	N*		
	.1562		22.86	18.17	16.82		10.59	S		
	.1586		22.52	18.08	17.25		11.02	N		
5	.1500	40.38	22.43	21.42	20.60	214	14.20	S*	15.81	28
	.1537		21.89	23.58	23.81		17.41	N*		
	.1312		25.65	30.00	22.07		15.67	S		
	.1499		22.45	25.58	24.56		18.16	N		
	.1468		22.92	26.75	24.64		18.24	S		

(continued)

Table 2 - (Continued)

Bicycle No.	Bicycle Speed Elapsed Time A	Wheel Base B	Speed B/12A= C	Stopping Distance D	Speed corrected Distance $E=(22/C)^2D$	Bicycle Payload (a) F	Load corrected Distance G	Direction H	Avg best I (e)	% Var $(\frac{Max}{Min}-1)100$ J
	sec	in	ft/sec	ft	ft	lb	ft	N or S	ft	
6	.1465	41.00	23.32	19.33	17.20	214	10.80	S*	11.03	13
	.1442		23.69	19.66	18.60		12.20	N		
	.1390		24.58	21.58	17.29		10.89	S		
	.1427		23.94	20.92	17.66		11.26	N*		
7	.1566	42.17	22.44	16.25	15.62	170.3	13.59	N*	14.10	16
	.1617		21.73	16.25	16.65		14.62	S*		
	.1611		21.81	16.66	16.94		14.91	N		
	.1480		23.74	20.25	17.38		15.35	S		
	.1578		22.27	18.25	17.81		15.78	N		
8	.1547	41.55	22.38	16.66	16.10	214	9.70	S*	9.80	14
	.1519		22.79	17.50	16.30		9.90	N		
	.1404		24.66	21.75	17.30		10.90	S		
	.1509		22.95	17.83	16.39		9.99	N		
	.1474		23.49	19.92	17.47		11.07	N		
9	.1306	41.12	26.24	23.17	16.28	173	13.98	N	16.28	78
	.1750		19.58	18.83	23.76		21.46	S		
	.1282		26.72	21.17	14.34		12.04	N*		
	.1729		19.82	18.25	22.82		20.52	S*		
10	.1552	41.66	22.37	16.66	16.11	186.3	12.48	N	11.45	20
	.1544		22.48	15.66	14.99	182.3	11.76	S		
	.1679		20.68	13.58	15.37		12.14	N		
	.1618		21.46	16.00	16.82		13.59	S		
	.1238		28.04	26.00	16.00	194.3	11.57	S*		
	.1558		22.28	16.17	15.76		11.33	N*		

(continued)

Table 2 - (Continued)

Bicy-cle No.	Bicycle Speed Elapsed Time	Wheel Base B	Speed B/12A= C	Stopping Distance D	Speed corrected Distance $E-(22/C)^2D$	Bicycle Payload (a)F	Load corrected Distance G	Direction H	Avg best I(e)	% Var $(\frac{Max}{Min}-1)100$ J
	sec	in	ft/sec	ft	ft	lb	ft	N or S	ft	
11	.1188	35.22	24.70	24.33	19.29	194.7	-	S*	20.07	20
	.1345		21.82	20.66	21.00		-	N		
	.1272		23.07	24.42	22.20		-	S		
	.1146		25.61	28.25	20.84		-	N*		
	.1302		22.54	22.58	21.51		-	N		
12	.1571	40.12	21.28	18.33	19.59	218	12.79	N	12.02	43
	.1534		21.79	18.17	18.51		11.71	S*		
	.1612		20.74	17.00	19.12		12.32	N*		
	.1549		21.58	22.67	23.55		16.75	S		
	.1473		22.70	22.50	21.14		14.34	S		
13(b,c)	.1376	30.25	18.32	10.00	6.41	120	-	S*	6.78	36
	.1496		16.85	9.42	7.14		-	N*		
	.1750		14.40	8.92	9.25		-	S		
	.1499		16.82	12.92	9.83		-	N		
14(b)	.1508	29.51	16.30	8.67	7.02	198.7	-	S*	6.38	15
	.1564		15.52	6.42	5.73		-	N*		
	.1481		16.60	11.00	8.58		-	S		
	.1623		15.15	8.08	7.57		-	N		
15	.1554	31.90	17.10	12.25	20.26	207.3	14.53	N*	14.60	20
	.1576		16.87	12.00	20.41		14.68	S*		
	.1613		16.48	12.83	22.86		17.13	N		
	.1437		18.50	16.33	23.09		17.36	S		

(continued)

Table 2 - (Continued)

Bicycle No.	Bicycle Speed Elapsed Time A	Wheel Base B	Speed B/12A= C	Stopping Distance D	Speed corrected Distance $E=(22/C)^2D$	Bicycle Payload (a) F	Load corrected Distance G	Direction H	Avg best I (e)	% Var $(\frac{Max}{Min}-1)100$ J
	sec	in	ft/sec	ft	ft	lb	ft	N or S	ft	
EXTENSION LEVER BRAKING SYSTEM										
5	.1421	40.38	23.68	17,50	15.10	194.7	10.63	S	9.71	49
	.1461		23.03	20.25	18.48		14.01	N		
	.1436		23.43	15.75	13.89		9.42	S*		
	.1429		23.55	16.58	14.47		10.00	N*		
6	.1518	41.00	22.51	17.92	17.12	194.7	12.65	S*	12.12	11
	.1421		24.04	19.17	16.05		11.58	N*		
	.1417		24.11	20.66	17.34		12.87	S		
	.1440		23.73	20.08	17.26		12.79	S		
	.1449		23.58	20.25	17.63		13.16	N		
8	.1411	41.55	24.54	13.66	10.98	194.7	6.51	S*	7.06	144
	.1375		25.18	15.83	12.08		7.61	N*		
	.1382		25.05	18.17	14.01		9.54	S		
	.1450		23.88	16.25	13.79		9.32	N		
	.1708		20.27	16.00	18.85	179.7	15.88	S		
	.1429		24.23	21.25	17.52		14.55	N		
	.1433		24.16	19.25	15.96		12.99	S		
	.1326		26.11	23.08	16.38		13.41	N		
	.1539		22.50	18.58	17.76	219.7	10.79	S		
	.1389		24.93	22.75	17.72		10.75	N		
	.1656		20.91	16.17	17.90		10.93	S		
	.1380		25.09	23.42	18.01		11.04	N		

(continued)

Table 2 - (Continued)

Bicycle No.	Bicycle Speed Elapsed Time A	Wheel Base B	Speed $B/12A=$ C	Stopping Distance D	Speed corrected Distance $E=(22/C)^2D$	Bicycle Payload (a) F	Load corrected Distance G	Direction H	Avg best I (e)	% Var $(\frac{Max}{Min}-1)100$ J
	sec	in	ft/sec	ft	ft	lb	ft	N or S	ft	
12	.1439	40.12	23.23	13.50	12.11	179.7	9.14	S*	10.86	71
	.1363		24.53	19.33	15.55		12.58	N*		
	.1417		23.59	21.42	18.63		15.66	S		
	.1329		25.16	22.33	17.07		14.10	N		

(a) Payload includes rider weight plus equipment weight.

(b) Tested from 10 mph.

(c) The bike was too small for the standard rider. A weight correction of 1 ft per 10 lb needed to reach 150 lb payload was added to the stopping distances.

(d) If run 1 were discarded.

(e) Average of the shortest stopping distances obtained for runs in each direction.

*This signifies the best stopping distance measured in each of the directions run. The numerical average of these two distances is given as the average best stopping distance.

Note: U.S. Customary Units of measurement have been used in this table. The appropriate conversion factors from the Customary Units to the SI system of units are provided below:

To convert from	to	multiply by
in	m	2.54×10^{-2}
ft	m	3.048×10^{-1}
ft/sec	m/sec	3.048×10^{-1}
lb	kg	4.536×10^{-1}

Table 3 - Effect of Braking Surface

Bicycle No.	Bicycle Speed Elapsed Time sec	Wheel Base in	Speed ft/sec	Stopping Distance ft	Corrected Distance ft	Average ft	Percent Variation
TEST ON OUTSIDE SURFACE							
COEFFICIENT OF FRICTION 1.22							
13	.1376	30.25	18.32	10.00	6.41	6.78	36
	.1496		16.85	9.42	7.14		
	.1750		14.40	8.92	9.25		
	.1499		16.82	12.92	9.83		
TEST ON INSIDE SURFACE							
COEFFICIENT OF FRICTION 0.55							
13	.1670	30.25	15.09	12.50	11.81	11.26	4
	.1591		15.84	13.42	11.50		
	.1584		15.91	13.25	11.26		
	.1590		15.85	13.25	11.34		

Note: U.S. Customary Units of measurement have been used in this table. The appropriate conversion factors from the Customary Units to the SI system of units are provided below:

to convert from	to	multiply by
in	m	2.54×10^{-2}
ft	m	3.048×10^{-1}
ft/sec	m/sec	3.048×10^{-1}
lb	kg	4.536×10^{-1}

Table 4 - Braking Test Results - Reaction Times

Bicycle No.	Distance Traveled 0# to 40# A	Elapsed Clock Time at Speed B	Bicycle Wheel Base C	Time to Load to 40# B/C x A	Distance Traveled L-R Coordination D	Elapsed Clock Time at Speed B	Bicycle Wheel Base C	Difference Time L-R Coordination B/C x D
	in	sec	in	sec	in	sec	in	sec
2	15	.1606	40.46	.059				
	20	.1571		.074				
	24	.1477		.088				
4	25	.1577	42.86	.092				
	23	.1586		.085				
5	15	.1537	40.38	.057	10	.1500	40.38	.037
	21	.1312		.068	15	.1312		.049
	26.5	.1499		.098	24	.1499		.089
6	30.5	.1427	41.00	.106	15.5	.1427	41.00	.054
					18.5	.1390		.063
7	44	.1566	42.17	.163				
	24.5	.1617		.094				
	29.5	.1611		.113				
	89	.1480		.312				
	60	.1578		.224				
8	35.5	.1547	41.55	.132	8.5	.1547	41.55	.032
	32.5	.1519		.119	8.5	.1519		.031
	59.5	.1404		.201	13	.1404		.044
	27.5	.1509		.100				

(continued)

Table 4 - (Continued).

Bicycle No.	Distance Traveled 0# to 40# A	Elapsed Clock Time at Speed B	Bicycle Wheel Base C	Time to Load to 40# B/C x A	Distance Traveled L-R Coordination D	Elapsed Clock Time at Speed B	Bicycle Wheel Base C	Difference Time L-R Coordination B/C x D
	in	sec	in	sec	in	sec	in	sec
9	15	.1750	41.12	.064				
	8.25	.1282		.026				
10	27	.1552	41.66	.100				
	29	.1544		.107				
	21.5	.1618		.084				
	16.5	.1558		.062				
12	21	.1571	40.12	.082	5	.1571	40.12	.019
	17	.1612		.068	19	.1534		.073
	58	.1549		.224	1	.1473		.000
	13.5	.1473		.049				
15	25	.1613	31.90	.126				
	34	.1437		.153				

Note: U.S. Customary Units of measurement have been used in this table. The appropriate conversion factors from the Customary Units to the SI system of units are provided below:

to convert from	to	multiply by
in	m	2.54×10^{-2}
ft	m	3.048×10^{-1}
ft/sec	m/sec	3.048×10^{-1}
lb	kg	4.536×10^{-1}

APPENDIX

This appendix contains the engineering drawings for the test fixtures designed for these tests and the parts list of all equipment used.

The drawings are in a pocket

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

The brake performance criteria to be published as part of a mandatory regulation on bicycle safety requirements has been evaluated. Fifteen bicycles were tested in accordance with the regulation. A mathematical adjustment of the actual test speed of the bicycle to 24 km/hr (15 mph) is necessary before the weight allowance can be made to the stopping distance in the evaluation of these tests. A danger of injury to the test rider exists during the tests and future efforts shou be made toward replacement of these tests with a simpler laboratory procedure.

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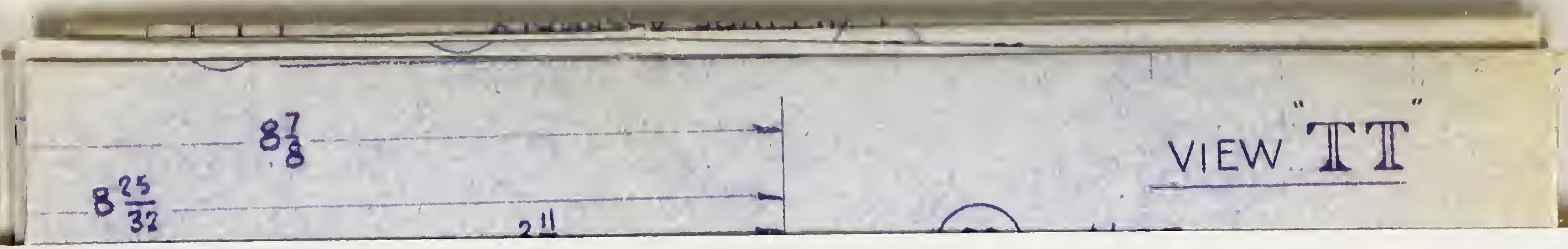
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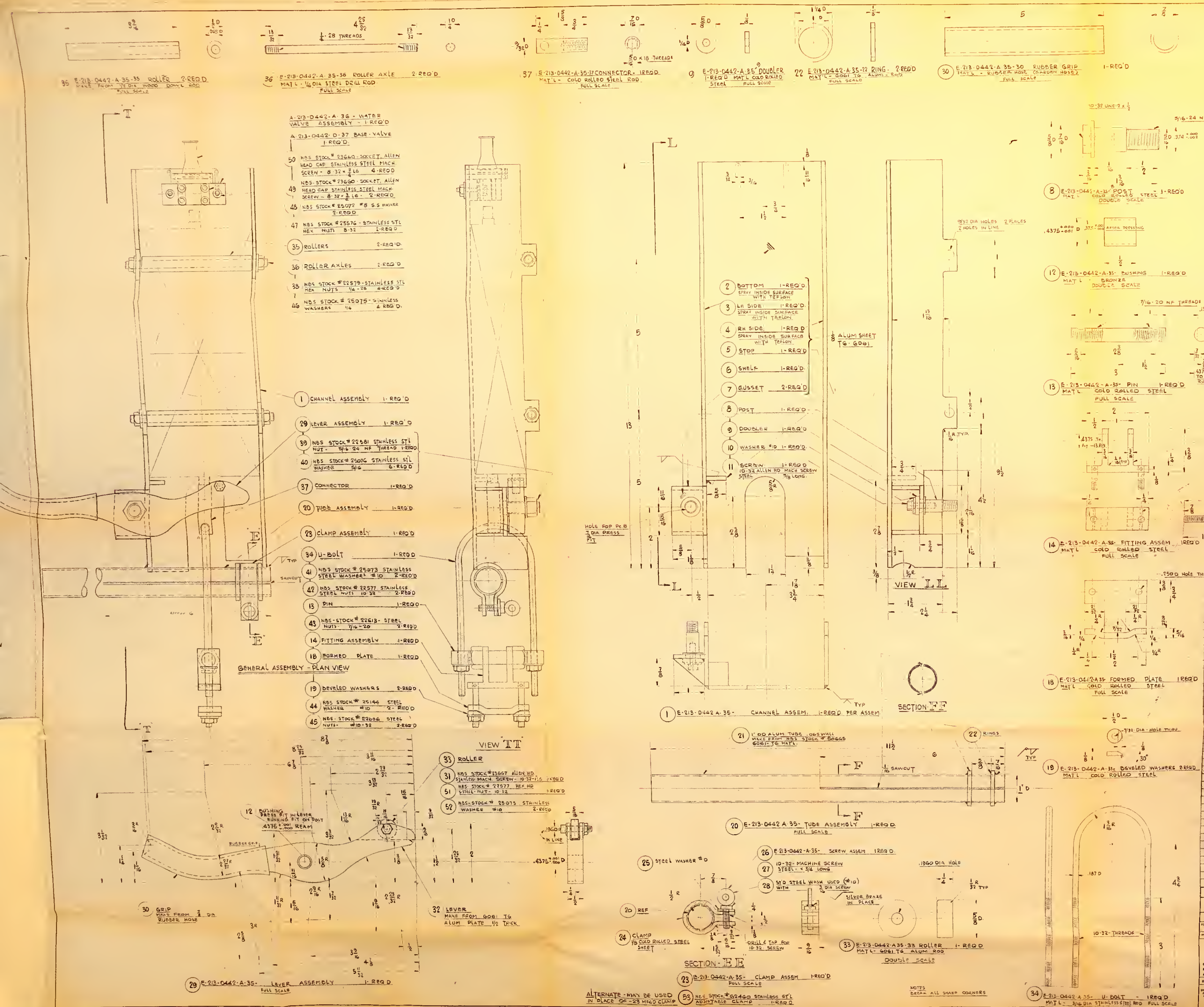

53	CLAMP - ADJ. HOSE	1
52	WASHER #10	2
51	NUT - STAINLESS HEX - 10 32	1
50	SCREW - ALLEN HD MACH STAIN ST'L	4
49	MACHINE SCREW STAINLESS ST'L	2
48	WASHER STAINLESS STEEL #8	2
47	NUT 8-32 STAINLESS STEEL	2
46	WASHER STAINLESS STEEL 1/4	4
45	NUT STEEL 10-32	2
44	WASHER STEEL #10	2
43	NUT 7/16-20 STAINLESS STEEL	2
42	NUT 10-32 STAINLESS STEEL	2
41	WASHER STAINLESS STEEL #10	2
40	WASHER STAINLESS STEEL 5/16	6
39	NUT 5/16-24 STAINLESS STEEL	1

38	NUT-1/4-28 STAINLESS STEEL	4
37	CONNECTOR	1
36	ROLLER AXLE	2
35	ROLLER WOOD DOWL	2
34	U-BOLT STAINLESS ST'L	1
33	ROLLER	1
32	LEVER	1
31	SCREW - ALLEN HD STAINLESS 10-32	1
30	RUBBER GRIP	1
29	LEVER ASSEMBLY	1
28	STEEL WASHER #10	1
27	MACHINE SCREW 10-32	1
26	SCREW ASSEM.	1
25	STEEL WASHER #10	1
24	CLAMP	1
23	CLAMP ASSEM.	1
22	ALUM - RING	2
21	ALUM - TUBE	1
20	TUBE ASSEMBLY	1
19	BEVELED WASHERS	2
18	FORMED PLATE	1
17	3/16 DIA ROD	2
16	1/16 DIA PIN OR ROLL PIN (OPT)	2
15	FITTING	1
14	FITTING ASSEMBLY	1
13	PIN	1
12	BUSHING	1
11	SCREW 10-32 STEEL	1
10	WASHER #10 STEEL	1
9	DOUBLER	1
8	POST	1
7	GUSSET	2
6	SHELF	1
5	STOP	1
4	RH SIDE	1
3	LH SIDE	1
2	BOTTOM	1
1	CHANNEL ASSEMBLY	1
	A 213-0442-A-36 WATER VALVE	1
	A-213-0442-D-37- BASE VALVE	1
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MODEL | TYPE | SCALE FULL & NOTED
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FRACTIONS ±.015
ANGLES ±1/2°
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